THE RELATIONSHIP BETWEEN PERCEIVED VELOCITY AND TRUE VELOCITY WHILE RUNNING VARIABLE SPEEDS

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DEDICATION

To my parents, whose faith and understanding made the completion of this investigation possible, this work is lovingly dedicated.

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CHAPTER I

ORIENTATION TO THE STUDY

Introduction

The relative abundance of research literature related to men's track and field is sharply contrasted by the lack of similar investigations involving women. Recently, interest in national and international competition for women has seen an associated increase in the number of studies on women participants.

Nikolay Osolin (1971) stated that movements performed at the same speed and rhythm reach the stage at which a further increase in speed does not seem possible. Osolin also reported that constant repetitions of movement cycles at a high speed may develop an automatic pattern of nervous processes that become set in the nervous system. If this hypothesis is true, it may be that a speed barrier develops and that the athlete may fail to make any further improvements in performance.

Both maximum velocity and speed endurance are qualities which contribute to the overall effectiveness of runners. Research conducted by Edwin Osolin (1973) indicated that variation in speed appeared to be one of the best methods to develop the components of sprinting, particularly speed endurance. The method seemed to be most successful when several speed variations were included in each repetition of the training exercise.

Purpose of the Study

The purpose of the study was to determine if true velocity and perceived velocity were the same when variable speeds were run over a specified distance. A secondary purpose of the research was to investigate stride length and stride rate while the variable speeds were being run. This was done in order to determine if and when changes in velocity occurred.

Statement of the Problem

The investigation compared perceived velocities of seven-eighths, two-thirds, and one-half of maximum velocity. Nine females who were members of the 1976-77 Texas Woman's University track team served as subjects. The data collection phase of the study took place during May, 1977, at the Texas Woman's University in Denton, Texas.

Data were collected using photo-electric cells, electric timers, and cinematography as the female runners performed a series of 60 m fly-ins. The results were analyzed in order to determine: (a) if perceived velocity was the same as true velocity when running at variable speeds, and

(b) if there were differences in stride length and stride rate when running at variable speeds.

Hypotheses

The specific purpose of this study was to test the following hypotheses at the .05 level of significance:

1. There is no significant difference in perceived velocities and true velocities of runs performed at one-half of maximum speed.

2. There is no significant difference in perceived velocities and true velocities of runs performed at two-thirds of maximum speed.

3. There is no significant difference in perceived velocities and true velocities of runs performed at seven-eighths of maximum speed.

The secondary purpose of the study was to investigate stride length, stride rate, and velocity from an empirical viewpoint. The following questions were of interest:

4. What are the variations in stride length over the 60 m fly-in?

5. What are the variations in stride rate over the 60 m fly-in?

6. What are the variations in velocity over the 60 m fly-in?

Definitions and/or Explanations of Terms

For the purpose of clarification, the following definitions and/or explanations were established for use in the study. The terminology used was consistent with the research encountered in track and field, both in this country and abroad; however, certain terms may have slightly different or more detailed definitions when used by those in the area of biomechanics.

Fly-in

A 60 m run beginning from a standing position five yards behind the starting line.

Perceived Velocity

Perceived velocity referred to the subject's actual recorded time for the variable speeds of one-half, two-thirds, and seven-eighths.

Calculated True Velocity

The calculated true velocity for one-half speed was computed from the subject's maximum recorded time for the 60 m fly-in which was multiplied by 2 and then divided by 1. The calculated true velocity for two-thirds speed was computed from the subject's maximum recorded time for the 60 m fly-in which was multiplied by 3 and then divided by 2. The subject's maximum recorded time for the 60 m fly-in was multiplied by 8 and then divided by 7 to arrive at the calculated true velocity for seven-eighths speed.

Electric Timer

The electric timer, developed by Electronic Ideals, Inc., of Denton, Texas, consisted of seven digital clocks, all of which were started simultaneously when the subject passed the first digital clock at the start of the 60 m fly-in. Each of the other digital clocks, in turn, registered the time at the 10, 20, 30, 40, 50, and 60 m marks.

Cinematography

"Cinematography involves the use of the motion picture camera to record motion for the subsequent kinesiological analysis" (Logan & McKinney, 1970, p. 195).

Stride Length

The investigator accepted the definition of Slocum and James (1968), who stated that stride length is defined as a cycle of motion which starts when one foot strikes the ground. The cycle may be designated a right or left stride. For the purpose of this study, stride length refers to that horizontal distance as measured between contact of the ball of the right foot to contact of the ball of the left foot.

Stride Rate

While sprinting, the leg speed determined by strides per second.

Variable Speed

For the purpose of this study, variable speeds referred to runs performed at different tempos, including one-half, two-thirds, and seven-eighths of the maximum performed time of each runner.

Speed Endurance

The ability to maintain a specific velocity for a given time or distance.

Maximum Velocity

Highest rate of velocity a runner can generate.

Delimitations of the Study

The study was subject to the following delimitations:

1. The cooperation of the female runners of the Texas Woman's University track team who served as subjects.

2. The degree to which environmental conditions remained constant.

3. The validity and reliability of the instruments.

4. Nine highly skilled female runners who were undergraduates at the Texas Woman's University.

5. The variable speeds were based on the maximum which was the first fly-in performed on the day of data collection.

CHAPTER II

REVIEW OF RELATED LITERATURE

An examination of the literature indicated that the investigation did not duplicate any previous research on female subjects. A review of the related literature pertinent to the study is presented in this chapter. The review is divided into three sections to present the literature in appropriate groupings. It should be noted here that the investigator found most of the related literature to be authoritative in nature rather than research oriented.

Chapter II is divided into the following sections: (a) Research Studies on Perceived Exertion, (b) Authoritative Opinions, and (c) Other Research Studies.

Research Studies on Perceived Exertion

Ekblom and Goldbarg (1971) studied the influence of physical training on the subjective rating of perceived exertion. They believed that an important question for work physiologists and psychologists was how an individual perceived the amount of work he was performing. Thus, a study was conducted to analyze the effects of an 8-week period of physical training on perceived exertion.

The subjects were 8 male subjects between the ages of

21 and 32 years. Exercise testing was done on the bicycle ergometer and work loads were chosen to demand approximately 25, 50, 75, and 100% of the individual's maximal oxygen uptake before and after training. In addition, after training the subjects performed the work load which was his maximum before the training began. Training consisted of 8 weeks of physical conditioning. The physical conditioning consisted mostly of outdoor cross country running and the subjects trained from 5 to 7 days per week.

The findings of the study indicated that maximal oxygen uptake increased from a mean value of 2.90 l/min. before training to 3.35 l/min. after training. For a given submaximal oxygen uptake, heart rate was about 15 beats/min. lower after the training compared to before the training. Maximal heart rate was unchanged. For oxygen uptake at submaximal work loads, the rate of perceived exertion was 1.5 to 2.0 points lower after the training, but the maximum remained unchanged. Related to relative oxygen uptake (oxygen uptake in percent of maximum before and after training) or heart rate, perceived exertion was the same before and after the training.

The investigators concluded that in the physical training experiments the perceived exertion for a given submaximal load was significantly lower after the training. Ekblom and Goldbarg believed that this is important to consider since a given work task in daily life activity, such as manual work, will be perceived easily. They further reported that if perceived exertion is related to the relative oxygen uptake or heart rate, the perceived exertion will be the same before and after training. The explanation given for the lower scoring at a given load after training was stated to be found in the relative lesser strain on the cardio-respiratory systems and in the improved function of the working muscles. This was found to be reflected in the lower oxygen deficit and blood lactate concentration.

Borg and Noble (1974) stated "that the perception of exertion is a direct indicator of the degree of physical stress and an indirect one of the physical working capacity" (p. 150). Measurements of working capacity have been calculated from ratings of perceived exertion during ergometer work and were found to be both reliable and valid. One such study was done by Borg and Noble who were concerned with work of short duration (less than one minute). The experiment was performed on 20 male subjects at a pedaling rate of 60 to 65 rpm. During each test the subjects were instructed to pedal for 30 sec. during which time the work load was continually increased from 0 to 2000 kpm/min. A special ergometer was used with an electronic braking system. The work load on this ergometer could be increased or decreased from 0 to 500 units/sec.

Each subject was evaluated twice. The test included both ascending and descending series. Immediately following, the subjects reported their perceptions of the change in work load according to the following three ratings: (a) the work changed most rapidly at the beginning, (b) the work load changed constantly, or (c) the work load changed most rapidly at the end of the work.

The findings as reported by Borg and Noble indicated that when the work load increased as the 0.4 or decreased as the 0.6 power of time the variation was judged to be linear. The means for the combined ascending and descending series were 1.8 for test 1 and 2.0 for test 2. The investigators reported that this method, which used only three rating categories and no numbers, revealed slightly higher exponents than other methods.

Authoritative Opinions

In the track and field world, Coach Valentine Petrovskiy (1973) introduced the "Brave New World of Sprinting" (p. 17). In his article, Petrovskiy described the training regimen of Valeriy Borzov. The training and technical analyses were conducted for a 6-year period prior to the time the Soviet sprinter won the 100 m race at the 1972 Olympic Games held in Munich, Germany. Valeriy Borzov became a 10.0 sec. 100 m sprinter, backed by a team of scientists who had decided mathematically how he was to function. During the course of training, test exercises were used year-round to determine the changes in Borzov's state of preparation and to judge the effectiveness of conditioning techniques. Different training methods were used to accomplish the specified degree of running velocity and endurance. Specific exercises, running fractional distances at maximal and near-maximal velocity, and repeat runs over fractions of the racing distance from both block and flying starts were all part of the overall training pattern. Training was intended to develop and maintain the starting spurt, maximum velocity, and speed endurance.

There has been a recent upsurge in sprinting performance in Finland. Otason (1976) reported that a more intense program of anaerobic endurance training could be the reason for this upsurge. The training program which Otason recommended included the following:

> 1. Tempo runs over 60 to 600 m (60% to 90% effort) with walk back recoveries of 2 to 6 min. to reduce the pulse rate to 120.
> 2. Repetition runs over 60 to 600 m (60% to 100% effort) with full recoveries over an average of about 8 to 10 min.
> 3. Tempo interval runs over 100 to 300 m (60% to 95% effort) with job back recoveries.
> 4. Interval sprints over 100 to 800 m: i.e., 30 m fast, followed by 30 m relaxed. (p. 1999)

Gosta Holmer (1972), the celebrated Swedish coach, established the informal fast and slow cross country running known as fartlek during the 1940's. Holmer used variable speeds in his training programs. Two times per week, one-quarter and one-half racing tempos were alternated in the work-out. During the last month, one-half to three-quarter racing tempos were used. Holmer reported that it was vital to be a well developed runner before variable speed training can be successfully utilized.

Karoblis, Krasaitene, and Krasaitis (1978) stated that "different volumes and intensities of training work are the instruments through which the functional changes aimed at development of specific motor qualities take place" (p. 2336). Tempo running is one method used in U.S.S.R. Tempo running is the running of distances from 6 to 12 km at a steady, high tempo. In tempo running, the movement coordination and functional and energy adjustments of the body systems take place against accumulating fatigue, in conditions that are as close as possible to competition.

The time for men, in the preparatory period, was 3:20 to 3:30 min. per km (depending on the condition of the runner), and for women, 3:50 to 4:00 min. per km. The investigators reported that such running facilitated development of the specific endurance needed by long distance runners and with minimal use of anaerobic energy sources, improved the circulatory system gradually and steadily. It also increased the power potential of energy conversion.

Karoblis et al. (1978) suggested that tempo running be used two times a week in the preparatory period and once weekly in the competition period.

Tabashchnikov (1979) reported that an analysis of the careers of world leading sprinters showed that best performances were reached after 8 or 9 years of training. It seemed to be a characteristic of most sprinters to achieve relatively fast times early in their careers and then level off or improve only slightly. In attempting to explain this sudden stagnancy after an early promising start, Tabashchnikov came to the conclusion that it was caused by poor long range planning and misunderstanding of basic sprint training principles. Many young sprinters lack proper all-round physical conditioning. Instead of following a plan to reach top performances at an optimal age, they have become victims of a rush to produce fast times as early as possible.

Tabashchnikov reports that according to Schernayev's studies, young Soviet sprinters have many shortcomings. Typical is the unbalanced strength development of different muscle groups and poor leg power; both affect the start and acceleration phase.

Much has been written about the dangers of forced training processes that are aimed toward rapid improvement, but it appears that coaches have taken little notice of this. Most are looking for immediate success rather than future development; they, therefore, continue with the old training methods. Others have changed to an extreme emphasis on all-round physical conditioning in which the athletes perform cross country runs and are involved in a large quantity of jumping and resistance exercises. The running mileage is made up of 150 to 300 m but the intensity is kept at a low level. In some cases, speed training has been completely ignored for as long as 6 months during the preparation phase of training. This type of training does not support the accepted theory of adaptation which requires a carefully adjusted training load and intensity for concrete results.

Tabshchnikov agrees with Petrovskiy in that a large amount of running performed below the competitive speed adjusts the organism to perform accordingly. As the result, the potential speed is not achieved. According to Petrovskiy, sprinting and speed exercises were essential in the development of sprinters, particularly after four or five years of training in the 18 to 19 age range. He felt it was essential during these ages to develop strength and power by using sprint specific methods and to avoid monotonous repetitions of the same type of training. Petrovskiy recommends: (a) varied resistance (uphill and downhill) sprinting, (b) changes in the running rhythm, and

(c) starting and accelerations to be incorporated into the training program.

Neel (1980) stated "that the goal of any sprinter is to accelerate the body to a maximum velocity in a straight line, and maintain uniform motion for a maximum time period" (p. 6). The human body is extremely complex, however, with many types of forces (chemical, physical, biological, mental, and environmental) acting on the sprinter as soon as he/she is in motion. Neel believed that depending on the sum total of these forces, the individual would continue to accelerate in a straight line if the forces were balanced, or begin to decelerate if confronted by unbalanced forces.

According to Neel (1980), the sprinter must be aware of the biomechanical principles involved in establishing correct running form. The factors which the researcher felt to be considered were as follows: (a) The position of the pelvis is the key to postural control in sprinting. The antero/postero rotation of the pelvis controls the motion of the lumbar spine, the degree of flexion of the thigh relative to the ground, and the degree of outward rotation of the hip. (b) The lower lumbar vertebrae, sacrum, pelvis, thighs, and legs provide the length, power, and motion that is necessary for sprinting. (c) The smoothness and efficiency of the stride are the result of minimal body displacement in the sagittal plane (front to back). There is maximal forward displacement at takeoff, and minimal deceleration by the leading leg at foot strike. (d) The position of the trunk should be erect, as this favors the flat-backed position of the lumbar spine in preparation for takeoff. It requires less effort in maintaining postural equilibrium, provides free movement of the scapula, and thus free movements of the arms. (e) At the completion of the recovery stroke, the higher the knee is lifted the greater the distance the foot can travel in its backward movement to the track and the greater force it can apply (considered the power stroke). (f) From a biomechanical viewpoint, the sprinter wants to get the body to move at the maximum possible speed during each thrust in the correct direction.

Schmolinsky (1978) defined speed as "the ability on the basis of the mobility of the nervous system and muscular apparatus, to perform movements at a certain velocity. Physically, velocity is expressed by the formula:

$$\text{Velocity} = \frac{\text{change in distance}}{\text{change in time}}\text{" (p. 38).}$$

Thorough analyses have shown that positive outcomes in most sports events were achieved by an acceleration of the body, which means that speed per unit of time was constantly increased. Acceleration was obtained by the coordinated strength and development of various muscle groups having imparted the highest possible speed to the body of the athlete.

Schmolinsky reported that speed is a function of stride length and stride frequency; the athlete who wishes to gain speed will either take longer strides, stride faster, or use a combination of the two. The curve of stride length, as reported by Schmolinsky, illustrated three definite phases: a phase of high acceleration, a relatively constant phase, and a phase of renewed acceleration. The duration of the first phases (starting section) was clearly dependent on the runner's level of skill. Top sprinters increased their stride length up to 45 m, whereas untrained runners came to the constant phase as early as 25 m. In all sprinters this phase ended after 92 to 93 m. The greater stride length during the third stage (the last 3 or 4 strides) reflected the runner's endeavor to counteract the loss of speed.

The curve representing the stride frequency also indicated three phases: the phase of maximal acceleration, the phase of gradual deceleration, and the phase of greater deceleration. The investigator reported that the widely accepted notion that while performing the 100 m dash the sprinter reaches the highest stride frequency during the first strides is wrong. There was a difference between beginning and top level performers relative to the point at which maximum speed was attained. Beginners reached maximum speed after as little as 10 to 15 m, whereas top performers reached it after 25 m. During the second stage, the curve for all runners was similar, however, top performers showed the least decrease in frequency. During the third phase the greater decrease in frequency appears between 90 to 95 m. The investigator reported that this phenomenon was related to the lengthening of strides over the final stretch.

The variations in speed in the 100 m race can also be subdivided into three phases: the acceleration, the maximum speed, and the reduction in speed. In the performance of 100 m sprints, speed actually increased to the maximum followed by a slight slowdown. The most striking difference between speed curves of experienced and less experienced runners was that acceleration during the starting phase was much more marked in the top performers. Furthermore, they were in a position to continue to accelerate while beginners had already reached maximum speed. The switch to this stage was between 22 to 35 m depending upon the ability of the individual. The distance to the stage of maximum speed also varied. Beginners reached maximum speed at approximately 20 m while more experienced runners reached maximum speed at 45 m and above. Schmolinsky is in agreement with the widely expressed opinion that the speed of a top performer is achieved up to 70 m and then speed endurance becomes a decisive factor for the last 30 m. Therefore, the length of the phase of deceleration depends on the ability of the sprinter.

Schmolinsky (1978) reported on the relationship between stride length, stride frequency, and running speed. It was stated that experienced runners achieved greater speed by increasing both length and frequency of stride. There were only gradual differences from one runner to another with regard to qualitative changes in the length and frequency of strides. During training, too much emphasis has been put on the increase of stride length and frequency. More emphasis should be put on the development of explosive strength in the muscles, thus allowing the athlete to take longer strides in a shorter time. The slow-down in the second half of the 100 m may be considered as an upset balance in the stride rhythm (length and frequency of strides); the reason for this was reported by Schmolinsky as being a decrease in stride frequency. It was also noted that the decrease in stride frequency was virtually independent of the skill level of the runner. Experienced runners were better equipped to accommodate the fatigue factor which tended to lower performance time by lengthening the stride somewhat during the second half of the distance.

According to Schmolinsky, a question arises as to "whether a decrease in stride frequency in top performers must be regarded as unavoidable or whether there are training means by which a consistent stride rate through the finish can be achieved" (p. 124).

Schmolinsky (1978) further reported that based on the speed pattern of 100 m sprints two forms of running should be practiced in sprint workouts:

> Running to improve acceleration
> --Crouch or high start with bursts over 20 to 40 m
> --Games requiring strong acceleration over 20 to 40 m
> --Bursts over 20 to 40 m, from walking or jogging
> --Long jump run-ups
> --Relay starts over 30 to 40 m
>
> Running schedules for improving maximum speed
> --Runs at speed from crouch start over 50 to 80 m
> --Flying sprints over 20 to 40 m
> --The approach run-up to maximum speed is of about 40 to 50 m
> --Run-ups with baton in relay training over 50 to 70 m
> --Maximum acceleration over 30 to 50 m, followed by coasting. Coasting must be performed in an easy, relaxed way, without visible slow-down.
> --Acceleration runs over 100 m with a maximum or less than maximum section of some 30 to 40 m
> --Acceleration runs over 100 to 150 m at maximum or submaximum speed with a medium section of 20 to 30 m, followed by 30 m coasting. (pp. 149-150)

Other Research Studies

Edwin Osolin (1973) conducted research in which he investigated speed endurance. His research was based on the difference between the curve of the running speed and the extended line of the optimal speed for the distance. In an attempt to discover the suitability of training methods designed to develop speed endurance, four training groups of male sprinters were established: Group I used repetition sprints over 40 to 50 m at maximum speed; Group II sprinted distances of 100 to 150 m at maximum speed; Group III ran repetitions of 80 to 100 m with variation of speed in each repetition; and Group IV trained by orthodox methods. Group IV served as the control group. The training loads and intensity were adjusted to make the training regimens as equal as possible for each of the four groups.

After the conclusion of a 10-week training period, the following average improvements in performance were found: Group I improved their performance 1.27%; it was noted that they had shortened their starting phase by a large margin. Group II had a 1.56% improvement and their speed towards the end of the distance had improved. Group III showed marked improvements in all phases of the distance; the average improvement for this group was reported as 2.51%. Group IV had the least amount of improvement, 1.10%. Osolin (1973) reported that variation in speed appeared to be the best method for the development of sprinting components, particularly speed endurance. The method was most successful when several variations were included in each repetition of the training regimen. Osolin notes that varied speed training has been successfully used by American sprinters for a long time. One of their best known methods comprises repetitions which are started fast, followed by free and relaxed running in the middle, and concluding with a maximum speed finish. The following training exercises were recommended:

> 1. Tempo-change sprints: 30 m maximum acceleration, plus 30 m free running, plus 30 m maximum speed.
> 2. Sprint fartlek: 200 to 300 m with the last athlete in line accelerating to overtake the field.
> 3. Varied speed repetitions: distances ranging from 100 to 200 m covered in accelerations at the start and finish with free wheeling in the middle.
> 4. Uneven track sprints: starting 20 to 25 m uphill (about 2 to 3 degrees), followed by a stretch on horizontal track before a fast finish downhill. (Osalin, 1973, p. 32)

Karol Hoffman (1972), after carrying out observations between 1960-1965, gathered numerous facts on stride length and stride rate of female sprinters. One of these research projects involved a group of 23 female sprinters and included many of the best sprinters in the world. Among the group were Wilma Rudolph, Edith McGuire, and Wyomia Tyus of the United States; Dorothy Hyman of Great Britain; Jutta Heine of West Germany; Giuseppina Leone of Italy, and Irena Kirszenstein Szewinska and Eva Klobukowska of Poland. The range of their times on the 100 m was from 11.0 to 12.4 sec.

The observations and measurements were collected exclusively during top class competitive events. The fundamental measuring instrument was a movie camera. The resulting film allowed the investigator to count the number of strides required to cover the various distances. During Polish championships, measurements were taken of four strides performed at full pace between the 50 to 60 m segment of the 100 m race. Knowing the time achieved by the female competitor and the total number of strides taken over the distance, the frequency of strides was estimated. In anticipation of certain similarities among the top class sprinters, two anthropometric measurements were taken: body height and the length of the lower limb (measured from the point of the trochanter). Hoffman reported the following conclusions:

> 1. It seemed clear that among top class female and male sprinters, there is a strong correlation between height and leg length with the length and frequency of stride.
> 2. The coefficients of correlation show a more significant relationship between the length and frequency of stride with the leg length than with height.
> 3. The measurements and observations carried out several times on the same competitors verify that the shortest build possess . . . the highest frequency of stride.
> 4. The best female sprinters when compared with male sprinters of the same class, height, leg length, and stride length run, however, about one second slower over the 100 m because of markedly lower frequencies of stride.
> 5. The results of the above, based on relatively limited sampling, still require verification from further research by measurement and observation. (p. 1524)

Cornett (1976) conducted a study the purpose of which was to investigate maximum speed of movement among female sprinters. The specific factors investigated were:

(a) the point in time and distance at which maximum velocity was attained; (b) the distance and/or time maximum velocity was maintained; and (c) the factors such as leg speed and stride length which influenced the attainment and maintenance of maximum velocity. The subjects were eight female sprinters from the Texas Woman's University track team. Three of the subjects were Olympians, two were members of the National track team, and the remaining three were skilled but not national caliber sprinters. Data were collected as the sprinters ran the 100 m dash. The subjects used starting blocks and were timed using photo-electric cells and electric timers as they performed the dash. Film data were also collected of each individual's performance. The study took place at the Texas Woman's University just prior to the National Championships and Olympic Trials in 1976.

Cornett reported the following results: (a) the average point in time at which maximum velocity was attained was 4.96 sec., and the average point in distance was 32.50 m. For the 5 superior performers the average was 5.05 sec. and for the 3 skilled runners it was 4.83 sec. (b) The average time for which maximum velocity was maintained was found to be 1.54 sec. and the average distance was 13.75 m. For the 5 superior performers the average time was 1.53 sec. while for the 3 skilled runners the average was 1.55 sec. (c) Acceleration comprised 38%, maximum 12%, and deceleration 50% of the total time for the 100 m dash.

Based upon the findings of this study the following conclusions were drawn by the investigator: (a) maximum velocity was reached at distances ranging from 30 m to 50 m and was held over distances ranging from 10 m to 20 m. Deceleration occurred at varying points from the 50 m mark to the 70 m mark. (b) Maximum velocity involved a relatively small distance of the run - 14%, acceleration involved about 33%, and deceleration involved almost 53% of the run. (c) As stride frequency decreased from its highest rate during the acceleration phase, the increase in stride length more than compensated for the loss of leg speed during the maximum velocity phase.

CHAPTER III

METHODS AND PROCEDURES

The major purpose of the investigation was to determine if perceived velocities and true velocities were the same when variable speeds were run. The specific factors investigated were stride rate and stride length. This chapter includes a discussion of the preliminary procedures, selection and description of instruments, selection of subjects, procedures related to the collection of data, and procedures followed in analyzing the data.

Both human and documentary sources of data and information were utilized in the investigation. The human sources used as subjects in the investigation were nine female runners who were members of the Texas Woman's University track team. Other human sources included members of the thesis committee. Documentary sources included books, pamphlets and periodicals from throughout the world, other published and unpublished reports, microcards, and research pertinent to the investigation.

Preliminary Procedures

Information was assimilated which was pertinent to all phases of the proposed study. This information was used in the formulation of a tentative outline and the further development of the study.

The outline of the proposed investigation was developed by the investigator and approved by the members of the thesis committee. The outline was revised in accordance with suggestions offered by the committee; a prospectus of the approved study was filed in the Office of the Provost of the Graduate School at the Texas Woman's University.

An outline of the study was presented to the Human Subjects Review Committee of the Texas Woman's University for approval, which was subsequently given. The investigator also obtained approval to film from the subjects involved in the study.

Selection and Description of Instruments

The investigator used three cameras: a Bell and Howell 70-HR; a Bell and Howell 70-DR; and a Locam model 51, 16 mm made by the Redlake Corporation in Santa Clara, California.

The electric timer used in this study was developed by Electronic Ideals, Inc., of Denton, Texas, as part of a research project funded by the Texas Woman's University. This multiple timing system, with seven digital clocks, provided a breakdown of times for the analysis of each of the specified segments of 10, 20, 30, 40, 50, and 60 m as each runner ran a 60 m fly-in. Seven photo-electric cells, manufactured by Micro Switch, a division of Honeywell of Freeport, Illinois, were mounted on 36-inch pedestals so that the eye of the cell was 37 in. high. The timing gate was completed with an accompanying reflector being placed opposite each photo-electric cell at the corresponding height. The distance from each photo-electric cell to reflector was 84 in. Each photo-electric cell was connected to the electric timer.

Six of the digital clocks started simultaneously when the first timing gate, set at the starting line, was disrupted by the subject's body. As the subject ran through each timing gate, the clock of the electric timer at that gate stopped, recording the time to the nearest one-hundredth of a second. Each digital clock, in turn, registered the time at the 10, 20, 30, 40, 50, and 60 m marks.

Selection of Subjects

The investigator chose as subjects nine female runners who were members of the Texas Woman's University track team. They were informed as to the nature of the study by their track coach and the investigator. The subjects were a combination of sprinters, jumpers, middle distance and distance runners. Three individuals were considered outstanding sprinters, having been members of the National A.A.U. track team. The remaining subjects were highly skilled but were not of national caliber.

Collection of Data

Data for the study were collected using the electric-timer and the photo-electric cells to determine whether: (a) perceived velocity was the same as calculated true velocity when running variable speeds, and (b) if there were differences in stride length and stride rate when running at variable speeds. Film data were collected to determine how changes in stride length and stride rate would influence changes in velocity.

Each subject was tested individually. Subjects used a standing fly-in start approximately three meters from the first photo-electric cell. This allowed that subject to be in motion when the first timing gate was disrupted to begin the timing sequence. The subjects were timed at 10, 20, 30, 40, 50, and 60 m while running four different speeds: maximum, one-half, two-thirds, and seven-eighths speed. All subjects performed the first timed run at maximum speed. The performance order of the other speeds were randomly drawn for each subject.

The filmed data on each subject were collected by three cameras (Bell & Howell HR, Bell & Howell DR, and the Locam) which were placed on the infield, perpendicular to the track at a distance of 60 ft. from the edge of the first lane. The three cameras were arranged so that each one's view field overlapped that of the camera placed immediately to its side. This allowed the investigator to collect filmed data on each subject over the entire 60 m distance. Kodak Black and White Tri-X Reversal film, perforated at both edges, was used in the cameras; it was exposed at 64 frames per second.

Procedures Followed in Analyzing the Data

Using the data from the electronic timing device, time intervals were obtained for each of the 10 m segments. Data were recorded for each speed trial for each subject.

The stride length was determined by measuring the distance from touch-down of the left foot to touch-down of the right foot. In order to obtain a two-stride cycle and allow for differences in bilateral stride, a measurement from touch-down of the right foot to touch-down of the left foot was also obtained. Hurdles were lined up, one by one, next to each other for 60 m in the outside lane. These were used as the measuring standard.

The stride rate for each subject was calculated in the following manner. The difference in the times of two specified 10 m intervals was divided into 10 (distance of the interval) to determine meters/second. For example, time at the 20 m mark (2.81 sec.) was subtracted from time at the 30 m mark (3.95 sec.) which produced a total difference in time of 1.14 sec. for that interval. The resulting value expressed in meters/second was then divided by the stride length of one complete cycle (length from touch-down of right foot to the left foot and touch-down of left foot to right foot). This yielded the number of cycles/second which was then multiplied by 2 to determine the number of strides/second or stride rate (Cornett, 1976).

Chapter IV contains the presentation of the findings. Included in the chapter are analyses and conclusions based upon the data obtained.

CHAPTER IV

PRESENTATION OF THE DATA

Introduction

The data in this study were collected through the use of the electric timer, photo-electric cells, and cinematography on runners as they ran at variable speeds over 60 m. The subjects were nine female college age runners who were members of the Texas Woman's University track team. The purpose of the study was to determine if true velocity and perceived velocity were the same when variable speeds were run over a specified distance. A secondary purpose of the research was to investigate stride length and stride rate while the variable speeds were being run. This was done in order to determine if and when changes in velocity occurred. These data are presented in narrative and tabular form in this chapter.

Descriptive Information Regarding Subjects

Collection of the height and weight data were done in inches and pounds, respectively. However, the investigator converted these findings to metric units to report height in inches and centimeters and weight in pounds and kilograms.

Table 1 displays the height and weight data of the subjects. A review of the table reveals that the subjects ranged in height from 60 in. (150 cm) to 71 in. (177.50 cm) with an average of 65.92 in. (164.80 cm). The standard deviation for height was 3.796 in. (9.489 cm). The subjects were relatively homogeneous in height.

The subjects ranged in weight from 106 lbs. (47.70 kg) to 135 lbs. (60.75 kg) with the average weight being 122 lbs. (54.95 kg). The standard deviation for weight was 10.91 lbs. (4.91 kg). The subjects were less homogeneous in weight than in height.

Table 1

Descriptive Data of Subjects on the Variables of Height and Weight

Variable	_n_	_range_ (high-low)	_M_	_SD_
Height (in.)	9	11.00 (71-60)	65.92	3.796
Height (cm)	9	27.50 (177.50-150.00)	164.80	9.489
Weight (lbs.)	9	29.00 (135-106)	122.10	10.91
Weight (kg)	9	13.05 (60.75-47.70)	54.95	4.911

Perceived and Calculated True Velocities at One-Half Speed

The subjects were asked to run a 60 m fly-in at one-half of their maximum speed. The fly-in was timed and the results are presented in Table 2 as perceived velocity. The calculated true velocity was computed from each subject's maximum recorded time for the 60 m fly-in (see Definitions for formulas).

Table 2

Perceived and Calculated True Velocity
Data at One-Half Speed

Subjects	Perceived Velocity (in sec.)	Calculated True Velocity (in sec.)
1	8.20	14.56
2	8.60	16.46
3	8.41	15.84
4	8.01	15.10
5	8.34	15.20
6	8.51	16.04
7	9.99	16.90
8	7.99	15.04
9	8.73	15.02

As revealed in Table 2, the range for the subjects' perceived velocity was 2.00 sec. (7.99 sec. to 9.99 sec.). The range for the subjects' calculated true velocity was 2.34 sec. (14.56 sec. to 16.90 sec.).

Table 3 presents the results of a paired *t* test between the subjects' perceived velocities and their calculated true velocities at one-half speed. The mean for the perceived velocity was 15.57 sec. with the standard deviation reported as .776 sec. The standard error of the mean was .259 sec. The mean for the calculated true velocity was 8.53 sec. with a standard deviation of .602 sec. The standard error of the mean was .201 sec. Results of a paired *t* test showed that *t* (8 df) was equal to 40.83 ($p < .001$).

Table 3

Results of Paired *t* Test Between Perceived Velocity and Calculated True Velocity at One-Half Speed

Variable	*n*	M (sec.)	SD (sec.)	SEM (sec.)	*t**
Perceived Velocity	9	15.57	.776	.259	
					40.84**
Calculated True Velocity	9	8.53	.602	.201	

*$t_{.95} \leq 2.306$, two-tailed test

**$p < .001$ with 8 degrees of freedom

Perceived and Calculated True Velocities at Two-Thirds Speed

The same procedure was followed in the tabulation of the data for two-thirds speed as was done for one-half speed. The subjects were asked to run a 60 m fly-in at two-thirds of their maximum speed. The fly-in was timed and the results are presented in Table 4 as perceived velocity. The calculated true velocity was computed from each subject's maximum recorded time for the 60 m fly-in.

Table 4

Perceived and Calculated True Velocity
Data at Two-Thirds Speed

Subjects	Perceived Velocity (in sec.)	Calculated True Velocity (in sec.)
1	7.86	10.92
2	8.38	12.35
3	8.11	11.88
4	7.76	11.33
5	8.05	11.40
6	8.68	12.03
7	9.08	12.68
8	7.72	11.28
9	8.16	11.27

As revealed in Table 4, the range for the subjects' perceived velocity was 1.86 sec. (7.22 sec. to 9.08 sec.). The range for the subjects' calculated true velocity was 1.76 sec. (10.92 sec. to 12.68 sec.).

Table 5 presents the results of a paired _t_ test between the subjects' perceived velocities and calculated true velocities at two-thirds speed. The mean for the perceived velocity was 8.20 sec. with the standard deviation reported as .449 sec. The standard error of the mean was

.150 sec. The mean for the calculated true velocity was 11.68 sec. with the standard deviation reported as .583 sec. The standard error of the mean was .194 sec. Results of a paired _t_ test showed that _t_ (8 df) was equal to 35.31 ($p < .001$).

Table 5

Results of Paired _t_ Test Between Perceived Velocity and Calculated True Velocity at Two-Thirds Speed

Variable	_n_	_M_ (sec.)	_SD_ (sec.)	_SEM_ (sec.)	_t_*
Perceived Velocity	9	8.20	.449	.150	
					35.31**
Calculated True Velocity	9	11.68	.583	.194	

*$t_{.95} \leq 2.306$, two-tailed test

**$p < .001$ with 8 degrees of freedom

Perceived and Calculated True Velocities at Seven-Eighths Speed

The same procedure was followed in the tabulation of the data for seven-eighths speed as was done for one-half and two-thirds speed. The subjects were asked to run a 60 m fly-in at seven-eighths of their maximum speed. The fly-in was timed and the results are presented in Table 6 as perceived velocity. The calculated true velocity was computed from each subject's maximum recorded time for the 60 m fly-in.

Table 6

Perceived and Calculated True Velocity
Data at Seven-Eighths Speed

Subjects	Perceived Velocity (in sec.)	Calculated True Velocity (in sec.)
1	7.36	8.32
2	8.45	9.41
3	8.05	9.05
4	7.45	8.63
5	7.87	8.69
6	8.17	9.17
7	8.68	9.66
8	7.52	8.59
9	7.64	8.58

As revealed in Table 6, the range for the subjects' perceived velocity was 1.32 sec. (7.36 sec. to 8.68 sec.). The range for the subjects' calculated true velocity was 1.34 sec. (8.32 sec. to 9.66 sec.).

Table 7 presents the results of a paired *t* test between the subjects' perceived velocities and calculated true velocities at seven-eighths speed. The mean for the perceived velocity was 7.91 sec. with the standard deviation of .463 sec. The standard error of the mean was .154 sec. The mean for the calculated true velocity was 8.90 sec. with the standard deviation of .445 sec. The standard error of the mean was .148 sec. Results of a paired *t* test showed that *t* (8 df) was equal to 30.47 ($p < .001$).

Table 7

Results of Paired *t* Test Between Perceived Velocity and Calculated True Velocity at Seven-Eighths Speed

Variable	*n*	*M* (sec.)	*SD* (sec.)	*SEM* (sec.)	*t**
Perceived Velocity	9	7.91	.463	.154	30.47**
Calculated True Velocity	9	8.90	.445	.148	

$^{*}t_{.95} \leq 2.306$, two-tailed test

$^{**}p < .001$ with 8 degrees of freedom

Descriptive Information Regarding Stride Length, Stride Rate, and Velocity

The data collected on stride length, stride rate, and velocity have been gathered to answer empirically the following research questions: (a) what are the variations in stride length over the 60 m fly-in, (b) what are the variations in stride rate over the 60 m fly-in, and (c) what are the variations in velocity over the 60 m fly-in. The data are presented in the form of graphs. The average of the nine subjects' stride length, stride rate, and velocity for one-half, two-thirds, seven-eighths, and maximum speed are presented in 10 m segments from start through 40 m for stride length and stride rate, and through 60 m for velocity. Stride length and stride rate were presented through 40 m because the camera that filmed the 40 m to 60 m segment did not operate properly and the data were lost.

Figure 1 is a representation of the subjects' average stride length. The range for the subjects' average stride length was found to be 1.27 m (1.42 m to 2.69 m). The minimum stride length of 1.42 m occurred during the 10 m segment at maximum speed while the maximum stride length of 2.69 m occurred during the 40 m segment at one-half speed. During the 10 m segment of the run, the average stride lengths for the variable speeds were: (a) one-half speed, 1.65 m; (b) two-thirds speed, 1.61 m; (c) seven-eighths speed, 1.61 m;

and (d) maximum speed, 1.60 m. During the 20 m segment of the run, the average stride lengths for the variable speeds were: (a) one-half speed, 1.90 m; (b) two-thirds speed, 1.88 m; (c) seven-eighths speed, 1.80 m; and (d) maximum speed, 1.83 m. During the 30 m segment of the run, the average stride lengths for the variable speeds were: (a) one-half speed, 2.35 m; (b) two-thirds speed, 2.31 m; (c) seven-eighths speed, 2.33 m; and (d) maximum speed, 2.32 m. During the 40 m segment of the run, the average stride lengths for the variable speeds were: (a) one-half speed, 2.39 m; (b) two-thirds speed, 2.40 m; (c) seven-eighths speed, 2.33 m; and (d) maximum speed, 2.36 m.

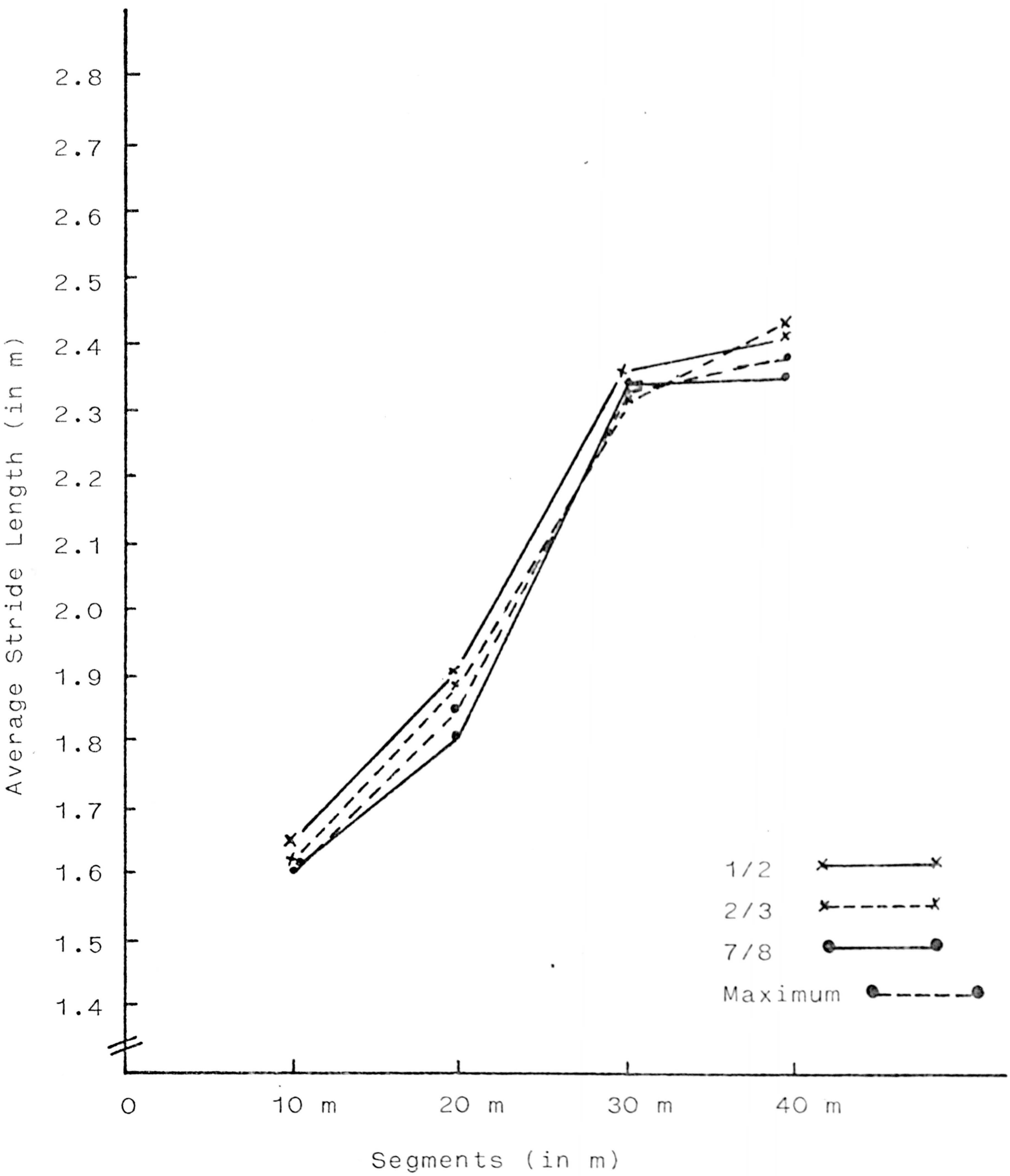

Figure 1. Average stride lengths for each 10 m segment through 40 m.

A representation of stride rate is shown in Figure 2. The average stride rate ranged from 2.86 strides/sec. for the slowest cycle of leg speed to 5.66 strides/sec. for the fastest cycle of leg speed. The 5.66 strides/sec. occurred in the 10 m segment at two-thirds speed while the 2.86 strides/sec. was noted in both the 30 m segment and the 40 m segment at one-half speed and were performed by the same subject. During the 10 m segment of the run, the average stride rates for the variable speeds were: (a) one-half speed, 4.36 strides/sec.; (b) two-thirds speed, 4.61 strides/sec.; (c) seven-eighths speed, 3.82 strides/sec.; and (d) maximum speed, 4.05 strides/sec. During the 20 m segment of the run, the average stride rates for the variable speeds were: (a) one-half speed, 3.91 strides/sec.; (b) two-thirds speed, 4.11 strides/sec.; (c) seven-eighths speed, 4.22 strides/sec.; and (d) maximum speed, 4.22 strides/sec. During the 30 m segment of the run, the average stride rates for the variable speeds were: (a) one-half speed, 3.17 strides/sec.; (b) two-thirds speed, 3.39 strides/sec.; (c) seven-eighths speed, 3.44 strides/sec.; and (d) maximum speed, 3.50 strides/sec. During the 40 m segment of the run, the average stride rates for the variable speeds were: (a) one-half speed, 3.20 strides/sec.; (b) two-thirds speed, 3.31 strides/sec.; (c) seven-eighths speed, 3.46 strides/sec.; and (d) maximum speed, 3.50 strides/sec.

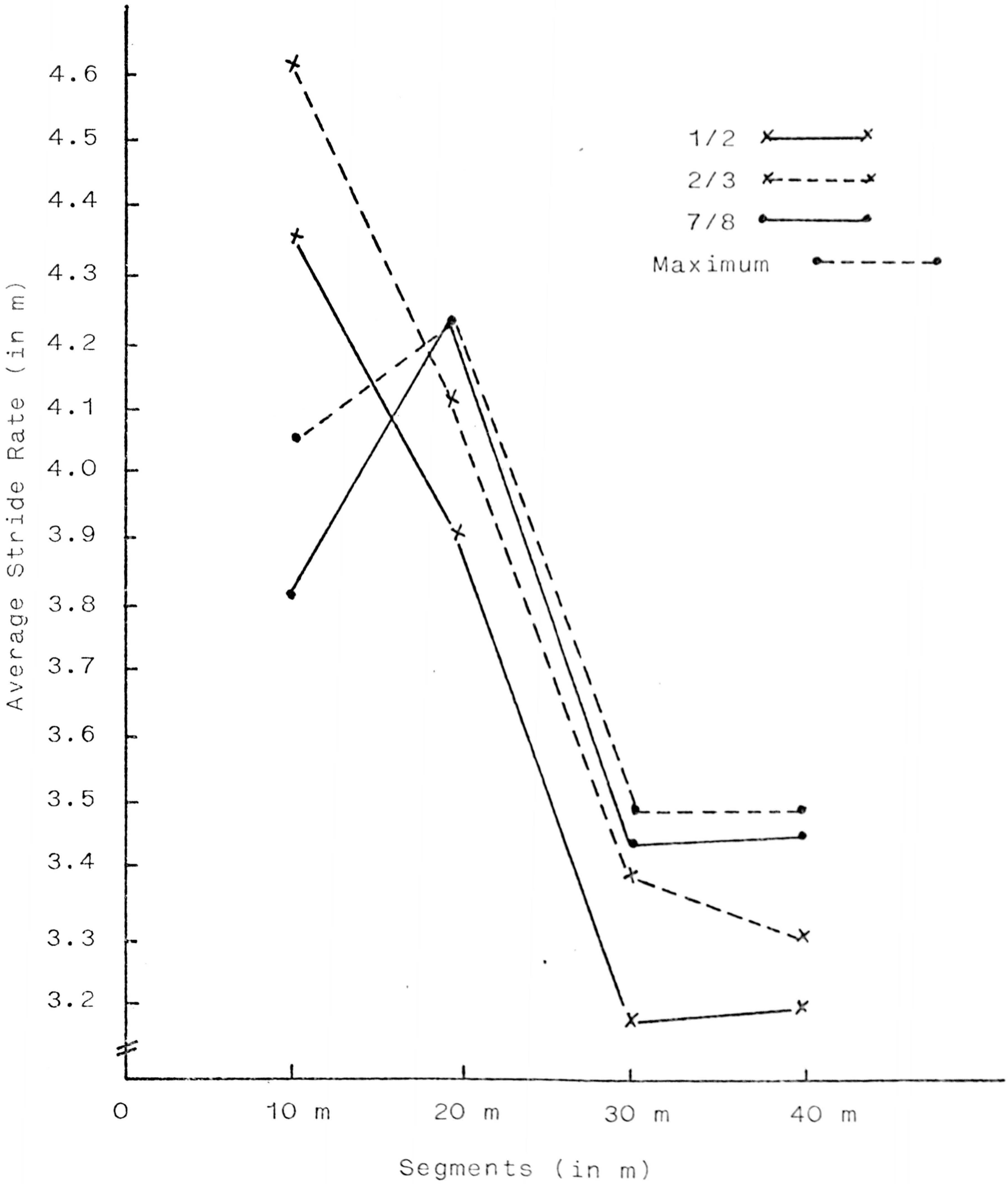

Figure 2. Average stride rates for each 10 m segment through 40 m.

The subjects' average velocity is presented in Figure 3. The average velocity ranged from 1.08 sec. for the fastest segment to 2.01 sec. for the slowest segment. The 1.08 sec. was found in the 50 m segment at maximum speed while the 2.01 sec. occurred in the 10 m segment at one-half speed. During the 10 m segment of the run, the average velocities for the variable speeds were: (a) one-half speed, 1.71 sec.; (b) two-thirds speed, 1.67 sec.; (c) seven-eighths speed, 1.63 sec.; and (d) maximum speed, 1.60 sec. During the 20 m segment of the run, the average velocities for the variable speeds were: (a) one-half speed, 1.43 sec.; (b) two-thirds speed, 1.37 sec.; (c) seven-eighths speed, 1.33 sec.; and (d) maximum speed, 1.29 sec. During the 30 m segment of the run, the average velocities for the variable speeds were: (a) one-half speed, 1.35 sec.; (b) two-thirds speed, 1.30 sec.; (c) seven-eighths speed, 1.25 sec.; and (d) maximum speed, 1.23 sec. During the 40 m segment of the run, the average velocities for the variable speeds were: (a) one-half speed, 1.35 sec.; (b) two-thirds speed, 1.28 sec.; (c) seven-eighths speed, 1.23 sec.; and (d) maximum speed, 1.22 sec. During the 50 m segment of the run, the average velocities for the variable speed were: (a) one-half speed, 1.33 sec.; (b) two-thirds speed, 1.27 sec.; (c) seven-eighths speed, 1.23 sec.; and (d) maximum speed, 1.20 sec. The 60 m segment of the run produced the following average velocities for the variable speeds: (a) one-half speed, 1.37 sec.; (b) two-thirds speed, 1.31 sec.: (c) seven-eighths speed, 1.25 sec.; and maximum speed, 1.24 sec.

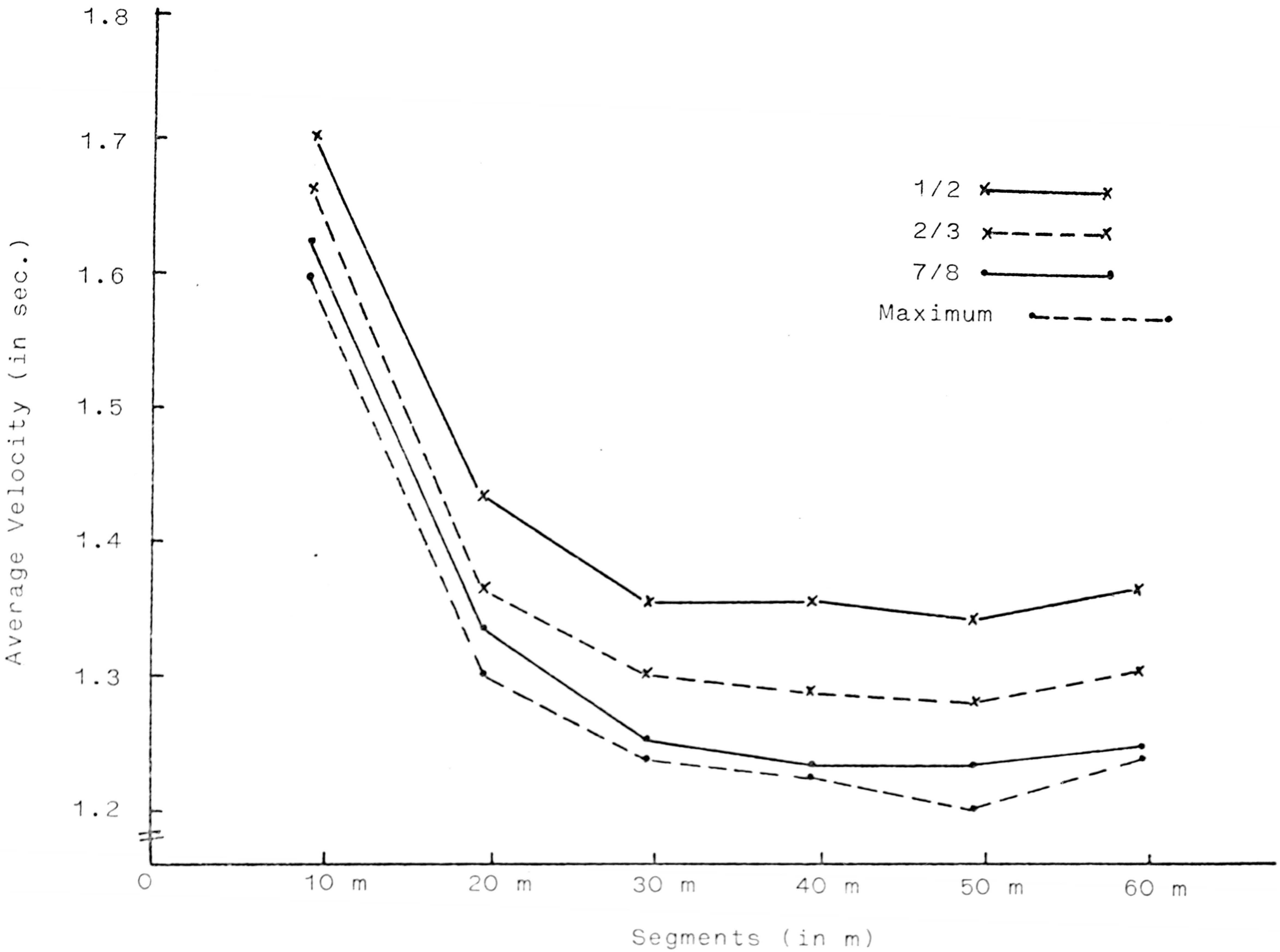

Figure 3. Average velocities for each 10 m segment through 60 m.

CHAPTER V

SUMMARY, CONCLUSION, AND RECOMMENDATIONS FOR FURTHER STUDIES

Summary of the Investigation

The investigation entailed a study of the running of variable speeds. The major purpose of the investigation was to determine if perceived velocity and true velocity were the same when variable speeds were run. The specific factors of stride length and stride rate were investigated to determine if and when changes in velocity occurred. A review of the literature indicated that the present study did not duplicate any previous investigations involving male or female runners with respect to the running of variable speeds. The research did indicate, however, that variable speeds are being used in different training programs.

Preliminary procedures included securing permission from the Human Subjects Review Committee to do the proposed study, developing a tentative outline which was presented to the thesis committee and, in corrected form, filed as a prospectus in the Office of the Provost of the Graduate School. Nine female college aged runners from Texas Woman's University track team were selected as subjects.

The investigator selected the electronic timer, photoelectric cells, and cinematography for data collection. Procedures were developed and each subject was timed and filmed according to established criteria. The study took place during May, 1977, at the Texas Woman's University in Denton, Texas.

This chapter summarizes the findings of the study and a conclusion is drawn. Recommendations for further studies are offered.

Findings

The study investigated specific research hypotheses and questions. As a means of synthesis, the findings relative to each are presented as follows:

1. Results of a paired *t* test showed that there was a significant difference between perceived velocity and calculated true velocity at one-half speed.

2. There was a significant difference between perceived velocity and calculated true velocity at two-thirds speed as shown from the results of a paired *t* test.

3. For seven-eighths speed, the results of a paired *t* test showed that there was a significant difference between perceived velocity and calculated true velocity.

4. Stride length, on the average, increased over 40 m except for seven-eighths speed where the length was the

same in the 30 m segment and the 40 m segment.

5. Stride rate, on the average, decreased up to 30 m for one-half and two-thirds speed with a slight increase at the 40 m mark. Stride rate for seven-eighths speed decreased constantly through the 40 m segment. At the maximum speed, the rate decreased up to the 30 m mark and was then constant through the 40 m segment.

6. Velocity, for all speeds, improved to the 50 m mark and then showed a slight decrease through the 60 m segment.

Conclusion

Based on the findings of this study, the investigator concluded that there was a difference between perceived velocity and calculated true velocity when running variable speeds.

Discussion

When the subjects were asked to run the variable speeds of one-half, two-thirds, and seven-eighths of their maximum speeds, the subjects did not know what the corresponding finish times should be for each of the speeds. The purpose of this study was to determine if the subjects could correctly perceive the variable speeds assigned in relation to their maximum effort. To accommodate the variable speeds, the subjects made their largest adjustments in velocity during the 10 m to 20 m segment. Velocities during the other segments were fairly constant.

Maximum velocity was reached by 50 m for one-half, two-thirds, seven-eighths, and maximum speeds. This is in agreement with Cornett's (1976) study in which she found that maximum velocity was attained between 30 m to 50 m. However, this study does not support Cornett's finding that maximum velocity is held for 10 m to 20 m. It was found, rather, that a decrease in velocity first occurred at the 60 m mark.

A review of stride length for the variable speeds showed that stride length was longest with the slower speed. An average of the subjects' stride length showed that, for all speeds, the greatest variability from segment to segment occurred in the 20 m to 30 m segment.

An average of the subjects' stride rate for all speeds showed that the greatest variability from segment to segment occurred during the 20 m to 30 m segment. It is postulated that both the factors of stride length and stride rate were adjusted in an attempt to vary velocity for the three variable speeds.

The three highly skilled subjects were closer in their perception of the variable speeds than were the skilled subjects. The investigator postulates that this was because the three highly skilled subjects had more practice with variable speed running.

Recommendations for Further Studies

The following are recommended for further research studies:

1. Replicate the study using male subjects.

2. Replicate the study using European athletes who have trained with a variable speed regimen.

3. Test subject's perception of variable speeds after one year of training consistently at variable speeds.

4. Conduct analyses of stride length and stride rate to determine which factor is most important in the regulation of variable speed.

5. Conduct an experimental study comparing individuals trained using variable speeds with individuals not trained using variable speeds.

APPENDIX A

Physical Characteristics of the Subjects

Subjects	Height		Weight	
	in.	cm	lbs.	kg
1	63.75	159.38	112	50.40
2	64.00	160.00	114	51.30
3	60.00	150.00	106	47.70
4	71.00	177.50	135	60.75
5	67.00	167.50	132	59.40
6	71.00	177.50	132	59.40
7	62.00	155.00	114	51.30
8	67.50	168.75	132	59.40
9	67.00	167.59	132	59.40

APPENDIX B

Timed Segments

Subjects	Speed[a]	10 m	20 m	30 m	40 m	50 m	60 m
1	1/2	1.69	3.03	4.33	5.63	6.90	8.20
	2/3	1.58	2.91	4.16	5.40	6.61	7.86
	7/8	1.54	2.80	3.97	5.11	6.22	7.36
	Maximum	1.58	2.81	3.95	5.07	6.15	7.28
2	1/2	1.68	3.12	4.48	5.85	7.20	8.60
	2/3	1.62	3.01	4.34	5.68	7.01	8.38
	7/8	1.71	3.09	4.44	5.78	7.10	8.45
	Maximum	1.64	3.01	4.31	5.61	6.91	8.23
3	1/2	1.68	3.08	4.42	5.77	7.09	8.41
	2/3	1.69	3.05	4.33	5.60	6.85	8.11
	7/8	1.63	3.00	4.27	5.52	6.78	8.05
	Maximum	1.61	2.93	4.20	5.44	6.67	7.92
4	1/2	1.60	2.93	4.19	5.45	6.71	8.01
	2/3	1.58	2.88	4.12	5.32	6.53	7.76
	7/8	1.54	2.77	3.94	5.09	6.26	7.45
	Maximum	1.52	2.78	3.98	5.16	6.34	7.55
5	1/2	1.66	3.04	4.35	5.67	6.90	8.34
	2/3	1.68	3.04	4.30	5.54	6.78	8.05
	7/8	1.63	2.95	4.19	5.41	6.63	7.87
	Maximum	1.59	2.86	4.06	5.24	6.41	7.60

[a]Speeds reported in seconds

Timed Segments Continued

Subjects	Speed[a]	10 m	20 m	30 m	40 m	50 m	60 m
6	1/2	1.77	3.20	4.52	5.83	7.13	8.51
	2/3	1.78	3.24	4.60	5.92	7.28	8.68
	7/8	1.71	3.08	4.34	5.60	6.87	8.17
	Maximum	1.68	3.01	4.29	5.54	6.75	8.02
7	1/2	2.01	3.69	5.26	6.86	8.48	9.99
	2/3	1.84	3.37	4.82	6.25	7.63	9.08
	7/8	1.78	3.23	4.61	5.98	7.31	8.68
	Maximum	1.70	3.09	4.42	5.96	7.09	8.45
8	1/2	1.60	2.96	4.23	5.48	6.72	7.99
	2/3	1.63	2.89	4.11	5.31	6.50	7.72
	7/8	1.60	2.84	4.02	5.18	6.34	7.52
	Maximum	1.58	2.84	4.00	5.18	6.34	7.52
9	1/2	1.69	3.18	4.60	5.96	7.34	8.73
	2/3	1.64	3.02	4.34	5.61	6.86	8.16
	7/8	1.51	2.82	4.02	5.22	6.41	7.64
	Maximum	1.52	2.74	3.96	5.13	6.30	7.51
Average Means	1/2	1.71	3.14	4.49	5.83	7.16	8.53
	2/3	1.67	3.05	4.35	5.63	6.84	8.20
	7/8	1.63	2.95	4.20	5.43	6.66	7.91
	Maximum	1.60	2.90	4.13	5.35	6.55	7.79

APPENDIX C

Stride Lengths and Stride Rates

Subjects	Speed	10 m		20 m		30 m		40 m	
		S.L.[a]	S.R.[b]	S.L.	S.R.	S.L.	S.R.	S.L.	S.R.
1	1/2	1.63	4.52	1.86	4.16	2.49	3.12	2.43	3.24
	2/3	1.65	4.52	2.01	4.02	2.36	3.40	2.58	3.22
	7/8	1.575	4.18	1.59	5.10	2.435	3.52	2.40	3.54
	Maximum	1.78	3.50	1.91	4.34	2.40	3.62	2.435	3.66
2	1/2					2.115	3.38	2.17	3.40
	2/3	1.60	4.40	1.83	4.10	2.155	3.42	2.20	3.42
	7/8	1.58	3.60	1.75	4.06	2.25	3.26	2.24	3.30
	Maximum	1.60	3.92	1.80	4.02	2.27	3.38	2.315	3.34
3	1/2	1.60	4.36	1.80	4.12	2.25	3.26	2.25	3.34
	2/3	1.45	4.94	1.72	4.60	2.13	3.64	2.23	3.62
	7/8	1.45	4.12	1.80	4.02	2.25	3.48	2.25	3.52
	Maximum	1.45	4.18	1.61	4.62	2.20	3.58	2.20	3.66
4	1/2	1.86	4.08	2.10	3.76	2.625	3.02	2.69	2.98
	2/3	1.74	4.30	2.11	3.80	2.51	3.28	2.61	3.14
	7/8	1.83	3.54	1.92	4.16	2.615	3.26	2.60	3.36
	Maximum	1.71	3.88	2.03	3.82	2.58	3.20	2.66	3.20
5	1/2	1.65	4.36	1.98	3.86	2.50	3.08	2.50	3.22
	2/3	1.72	4.14	1.98	4.02	2.49	3.28	2.60	3.08
	7/8	1.68	3.66	1.91	3.94	2.435	3.32	2.435	3.36
	Maximum	1.68	3.74	1.85	4.26	2.375	3.46	2.435	3.48

Stride Lengths and Stride Rates Con't.

Subjects	Speed	10 m		20 m		30 m		40 m	
		S.L.[a]	S.R.[b]	S.L.	S.R.	S.L.	S.R.	S.L.	S.R.
6	1/2	1.70	5.24	1.98	3.82	2.44	3.14	2.48	3.12
	2/3	1.52	5.66	1.83	4.02	2.435	3.12	2.49	2.98
	7/8	1.70	3.46	1.93	3.74	2.41	3.28	2.435	3.26
	Maximum	1.70	3.38	1.91	3.86	2.435	3.20	2.51	3.16
7	1/2	1.60	3.80	1.83	3.48	2.16	2.86	2.14	2.86
	2/3	1.52	4.28	1.78	3.82	2.20	3.18	2.17	3.32
	7/8	1.50	3.72	1.75	4.02	2.12	3.50	2.115	3.38
	Maximum	1.42	5.64	1.72	4.24	2.09	3.66	2.14	3.44
8	1/2	1.58	4.52	1.88	4.24	2.395	3.32	2.435	3.32
	2/3	1.57	4.90	1.83	4.48	2.23	3.76	2.385	3.48
	7/8	1.47	4.18	1.70	4.78	2.27	3.72	2.28	3.78
	Maximum	1.52	4.16	1.83	4.34	2.18	3.94	2.26	3.74
9	1/2	1.65	4.02	1.83	3.84	2.23	3.32	2.185	3.30
	2/3	1.68	4.32	1.83	4.14	2.30	3.44	2.26	3.52
	7/8	1.71	3.92	1.83	4.16	2.27	3.66	2.23	3.68
	Maximum	1.55	4.28	1.83	4.48	2.36	3.42	2.26	3.84
Means	1/2	1.65	4.36	1.90	3.91	2.35	3.17	2.39	3.20
	2/3	1.61	4.61	1.88	4.11	2.31	3.39	2.40	3.31
	7/8	1.61	3.82	1.80	4.22	2.33	3.44	2.33	3.46
	Maximum	1.60	4.05	1.83	4.22	2.32	3.50	2.36	3.50

[a] S.L. represents stride length and is presented in meters.

[b] S.R. represents stride rate and is presented in strides/second.

APPENDIX D

Velocities for Variable Speeds[a]

Subjects	Speed	10 m	20 m	30 m	40 m	50 m	60 m
1	1/2	1.69	1.34	1.30	1.30	1.27	1.30
	2/3	1.58	1.33	1.25	1.24	1.21	1.25
	7/8	1.54	1.26	1.17	1.14	1.11	1.14
	Maximum	1.58	1.23	1.14	1.12	1.08	1.13
2	1/2	1.68	1.44	1.36	1.37	1.35	1.40
	2/3	1.62	1.39	1.33	1.34	1.33	1.37
	7/8	1.71	1.38	1.35	1.34	1.32	1.35
	Maximum	1.64	1.37	1.30	1.30	1.30	1.32
3	1/2	1.68	1.40	1.34	1.35	1.32	1.32
	2/3	1.69	1.36	1.28	1.27	1.25	1.26
	7/8	1.63	1.37	1.27	1.25	1.26	1.27
	Maximum	1.61	1.32	1.27	1.24	1.23	1.25
4	1/2	1.60	1.33	1.26	1.26	1.26	1.30
	2/3	1.58	1.30	1.24	1.20	1.21	1.23
	7/8	1.54	1.23	1.27	1.15	1.17	1.19
	Maximum	1.52	1.26	1.20	1.18	1.18	1.21
5	1/2	1.66	1.38	1.31	1.32	1.23	1.44
	2/3	1.68	1.36	1.26	1.24	1.24	1.27
	7/8	1.63	1.32	1.24	1.22	1.22	1.24
	Maximum	1.59	1.27	1.20	1.18	1.17	1.19

Velocities for Variable Speeds[a] Con't.

Subjects	Speed	10 m	20 m	30 m	40 m	50 m	60 m
6	1/2	1.77	1.43	1.32	1.31	1.30	1.38
	2/3	1.78	1.46	1.36	1.32	1.36	1.40
	7/8	1.71	1.37	1.26	1.26	1.27	1.30
	Maximum	1.68	1.33	1.28	1.25	1.21	1.27
7	1/2	2.01	1.68	1.57	1.60	1.62	1.51
	2/3	1.84	1.53	1.45	1.43	1.38	1.45
	7/8	1.78	1.45	1.38	1.37	1.33	1.37
	Maximum	1.70	1.39	1.33	1.34	1.33	1.36
8	1/2	1.60	1.36	1.27	1.25	1.24	1.27
	2/3	1.63	1.26	1.22	1.20	1.19	1.22
	7/8	1.60	1.24	1.18	1.16	1.16	1.18
	Maximum	1.58	1.26	1.16	1.18	1.16	1.18
9	1/2	1.69	1.49	1.42	1.36	1.38	1.39
	2/3	1.64	1.38	1.32	1.27	1.25	1.30
	7/8	1.51	1.31	1.20	1.20	1.19	1.23
	Maximum	1.52	1.22	1.22	1.17	1.17	1.21
Mean	1/2	1.71	1.43	1.35	1.35	1.33	1.37
	2/3	1.67	1.37	1.30	1.28	1.27	1.31
	7/8	1.63	1.33	1.25	1.23	1.23	1.25
	Maximum	1.60	1.29	1.23	1.22	1.20	1.24

[a] Speeds reported in seconds

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